

Instrumentation

Beam Intensity and Longitudinal Measurements

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The instrumentation to measure the Beam Intensity and bunch lengths is straight-forward extensions of the technology used in the Tevatron.

Fast Toroids are used to measure the injected beam intensity. They are located in injection lines and near the point of injection into the ring. They are typically used in measuring the transfer efficiency of beam lines since they share a common calibration.

Cost : \$4k per installation (includes support electronics of a sample and hold).

DCCT (Direct Current Current Transformer) measures the dc component of beam current with absolute accuracy $<1-2\%$. One is needed per beam pipe. They provide a reliable and redundant intensity measurement.

Cost: Commercially available along with front end electronics for \$25k/ installation.

SBD (Sampled Bunch Display) and **FBI** (Fast Bunch Integrator) both use a high bandwidth (3 kHz -6 GHz) Resistive Wall Detector (RWD) to measure individual bunch intensities. The SBD uses a fast scope to capture the waveform, while the FBI simply integrates over the rf bucket. The absolute accuracy of the SBD is $<2\%$, while the FBI is typically 5%. The update rate on the SBD is 2 Hz (with today's technology), while the FBI can work at turn by turn speeds. The SBD also measures the bunch length, but in order to measure the bunch length, it is important to preserve the bandwidth of the signal to the scope/digitizer. This could involve locating the scope near the detector, or converting the electrical signal into an optical one for transmission on a fiber).

Cost: One RWD (\$10k including helix cable, perhaps \$20k if fiber is used) installation per beam pipe, but only one SBD and FBI support system per Machine. Cost is \$40k (primarily the commercial scope/digitizer) for SBD, \$15k for the FBI.

Transverse Measurements

Currently the Tevatron uses 2 systems to measure the transverse size of the beam, a Flying Wire System and a Synchrotron Light Monitor. Both are described below. As the beam energy is increased, the transverse size of the beam decreases inversely proportional to the square root of energy (relativistic damping). This will make the measurement of transverse beam size more difficult than it is in the Tevatron. Larger lattice beta's will offset this effect somewhat, but not eliminate it entirely. Development effort will be needed for the current systems as well as new devices such as the Electron Beam Monitor.

Flying Wires (FW) fly a 30 micron diameter carbon filament wire through the beam. The interaction of the beam on the wire produces a shower (primarily pions) which are detected in downstream scintillators. This system should still work fine for 3 TeV machine, and at injection for the 50 GeV machine. It isn't clear how high in energy (before the beam gets too small) one

can go with this technology. A measurement at the B0 IR with small beam sizes (start of Run 2) should provide insight into this question. In any case the FW should be installed at a high beta region to maximize the beam size and increase the precision of the measurement. One installation is comprised of three FW's- two horizontal and one vertical in reasonable proximity to each other so they can share electronics and controls. In the case of a very large machine, it may be advantageous to install 2 sets of 3 wires at opposite sides of the ring in order to look for lattice inconsistencies.

Cost: It may be possible to locate the wire can so that it could fly through both beams pipes. Cost per installation \$100k.

Sync Lite uses synchrotron radiation from the edge of a dipole magnet to make a 2D (transverse), and 3D (transverse and longitudinal) measurement of beam size. A pickup mirror, internal to the beam pipe reflects the synchrotron light beam through a transparent window into a telescope where an image of the beam is formed. A system similar to the Tevatron one could easily be imagined for the 3 TeV machine, as long as a provision is made to collect the synchrotron light beam before it hits the wall of the beam pipe). A least 2 telescopes are needed (one for each beam pipe--for pp operation). A system for the 50 TeV machine will need **development** work to extend the telescope into the hard uv-xray (short wavelength λ) region in order contend with diffraction effects (scaling as $\lambda\gamma$) and with smaller beam sizes, (naively scaling as $\sqrt{\gamma^{-1}}$).

Cost: For a 2D system, \$75k for one installation, plus 2 man years (a physicist and an engineer spread over a 2 year period) of development of the new telescope. A 3 D system would add another \$250k, primarily for a streak camera. Most software would have already been done for the Tevatron version.

Electron Beam Monitor scans a 10 keV electron beam across the proton beam. By measuring the deflection one can infer the transverse charge distribution.(SSC was working on a device like this for the 20 TeV machine).

Cost: Estimate \$100k/installation, with 2 man-years of **development**. This work could be started in the Tevatron.

Multi-electrode pickup measures the rms of the beam (transverse and longitudinal using time slicing) . A Multi-electrode detector is sensitive to the beam multipoles. It is in principle possible to extract the moments of the charge distribution. The small beam pipe should be a plus here, although it would need to be round in shape. Although the SSC rejected this option as lacking the needed sensitivity, it should be reevaluated as a fast (and dirty) transverse beam size monitor.

Cost: \$20k for a detector (either a stripline or a resistive wall detector), and a man year of **development** (spread over a couple of years).